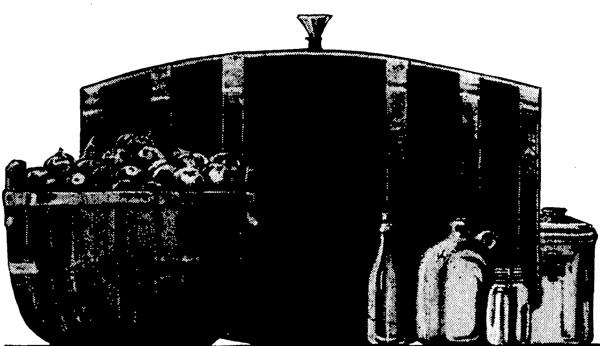
U. S. DEPARTMENT OF AGRICULTURE
FARMERS' BULLETIN No. 1424 Rev. July 1936

MAKING VINEGAR IN THE HOME AND ON THE FARM



VINEGAR can be made from any fruit, or, in fact, from any material which contains enough sugar and is in no way objectionable.

Whether it is done on a small scale in the home, on a larger scale on the farm, or on a still larger scale in the factory, the production of vinegar is the result of two distinct fermentation processes—an alcoholic fermentation followed by an acetic fermentation.

By using the materials and following the methods discussed in this bulletin, vinegar of good quality may readily be made from apples, peaches, grapes, and other fruits, large quantities of which are wasted each year in the United States.

Washington, D. C.

Issued June, 1924
Slightly revised July, 1936

MAKING VINEGAR IN THE HOME AND ON THE FARM.

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VINEGAR.

VINEGAR was first made from wine, as its name indicates, at a remote period. Biblical writers mentioned it and Hippocrates used it as a medicine. By the sixteenth century vinegar from grapes was being produced in France for home consumption and for export. In England vinegar was first made from malt liquors, a method of disposing of ale and beer which had soured. For this reason it was known as alegar. Although this name has long since become obsolete, malt vinegar is still the standard in the British Isles. It is not known just when vinegar was first made in the United States, certainly very early as a home product. Here apple juice is largely used for this purpose and cider vinegar is considered the standard for household purposes. Other fruits and vegetables, however, are coming more and more into favor for making vinegar. Spirit vinegar, now manufactured in large quantities in the United States, is extensively used for pickling purposes. There are few homes in which vinegar in some form is not used for flavoring, preserving, or pickling.

Vinegar is essentially a dilute solution of acetic acid, made by fermentation processes, containing salts and extracted matter. These additional substances, the exact nature and quantity of which depend upon the material used, give the product its distinctive quality. Sugar is the base of vinegar production. Any watery solution of a fermentable sugar may be transformed into vinegar under favorable conditions. Many fruit juices are well suited to this purpose, as they contain sugar in the proper proportion and other necessary or desirable substances.

All vinegar is made by two distinct biochemical processes, both of which are the result of the action of microorganisms. The first process is brought about by the action of yeasts which change the sugar into alcohol and carbon dioxide gas. This is the alcoholic fermentation. The second process results from the action of a widely distributed group of bacteria which have the power of combining oxygen with the alcohol, thereby forming acetic acid. This is the acetic fermentation, or acetification.

The following recognized varieties of vinegar are classified according to the material from which they are made and the methods of manufacture:

Vinegar made by the alcoholic and subsequent acetic fermentation of the juices of various fruits. Although apple juice is most commonly used for making vinegar in the United States, other fruit juices, notably those of grapes, peaches, oranges, persimmons, pineapples, and some berries, are satisfactory. Any fruit or vegetable containing enough sugar will serve the purpose.

Malt vinegar made by the alcoholic and subsequent acetic fermentation, without distillation, of an infusion of barley malt or other cereals in which the starch has been converted into maltose.

Sugar vinegar made by the alcoholic and subsequent acetic fermentation of solutions of sugar, sirup, or molasses.

Corn-sugar vinegar made by the alcoholic and subsequent acetic fermentation of a solution of cornstarch sugar or of glucose prepared from cornstarch.

Spirit or distilled vinegar made by the acetic fermentation of dilute distilled alcohol.

MATERIAL USED.

Anything may be used for making vinegar, so long as it contains enough sugar and is in no way objectionable. It would be difficult to describe in detail all the materials which are available for this purpose. The following are most commonly used in the United States:

APPLES.

Nearly all varieties of apples contain enough sugar to make vinegar of the required strength. This was well shown in three series of tests conducted by the Bureau of Chemistry on apples representing a large number of varieties grown during 1909, 1910, and 1911 in New York, Ohio, Virginia, Michigan, Missouri, and Washington. The average sugar content of the apples grown on grafted stock was found to be more than 13 per cent. In one series, including 58 varieties, in which two or more samples of each variety were analyzed (a total of 406 samples), the average sugar content was 13.34 per cent; in no sample was the sugar content less than 10 per cent. In a second series of 72 varieties, in which only one sample of each variety was analyzed, the average sugar content was 13.16 per cent; in only four of the varieties did the sugar content fall below 10 per cent. In a series of 75 samples of seedlings, natural fruit, the average sugar content was 12.71 per cent, the sugar content of none of the samples falling below 10 per cent.

Winter apples have the highest and summer apples the lowest average sugar content, with fall apples intermediate. Summer apples therefore are not suitable for vinegar making. Windfall apples may well be used for this purpose, provided they are not from summer varieties and were properly matured at the time of falling. Green apples are incapable of yielding a satisfactory vinegar, because much of their starch has not been transformed into sugar. Frosted or frozen apples have been used successfully for making

vinegar, but they must be pressed soon after freezing and before any rotting occurs.[1] Contrary to the usual belief, sweet apples are not richer in sugar than sour apples; in fact, some varieties may contain less than the average quantity. The sweet taste of these apples is due not to the presence of larger quantities of sugar but to a deficiency in malic acid, the acid normally present in apples.

Evaporated apple chops and the evaporated cores and parings obtained from apple-canning factories and apple-drying establishments are now used to some extent in the commercial production of vinegar. By passing water through several successive tanks of this material it is possible to obtain a sweet solution which serves for the production of vinegar. If the dried stock used for this purpose is clean and made from sound material, vinegar of satisfactory quality may be produced in this way. Such vinegar, however, is not made from the expressed juice of apples, so that when offered for sale it must be marked to show the material from which it is made.[2]

GRAPES.

Vinegar of unexcelled quality can be made from the grapes (*Vitis vinifera*) grown in Europe and on the Pacific coast of the United States. The white wine vinegar made from whole white grapes or from the pulp of purple or red grapes is excellent in quality. This must not be confused with what in commerce was formerly incorrectly called "white wine vinegar," which is simply a spirit vinegar. Grape vinegar can compete commercially with cider vinegar only on the score of merit and if it is to be sold at a profit "it must be made in such a manner as to produce and preserve those qualities to which it owes its reputation for superiority over all other classes of vinegar."[3]

Grape juice contains a very much higher proportion of sugar than apple juice; hence a much stronger vinegar can be made from it. The California Agricultural Experiment Station has shown that a ton of California grapes (20° Brix) can give on an average 150 gallons of juice, which will yield 135 gallons of vinegar containing 9.8 per cent of acetic acid. The Bureau of Chemistry has shown that vinegar of excellent quality can be made from the muscadine grapes grown in the Southern States. Juice from four varieties of these grapes (16.5° Brix) gave by household methods vinegar which contained an average of 6.6 per cent of acetic acid.

ORANGES.

The Bureau of Chemistry has shown that a very acceptable vinegar can be made from oranges, either on the household scale or on a commercial scale. Cull oranges will give a vinegar which not only is equal to the best grade of vinegar but can be made commercially at a cost which in some markets permits competition in price with apple vinegar.

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[1] A. R. Lamb and Edith Wilson. Vinegar Fermentation and Home Production of Cider Vinegar. Iowa Agr. Expt. Sta. Bul. 218 (1923), p. 5.
[2] U. S. Dept. Agr., Food Inspection Decision 140 (1912).
[3] F. T. Bioletti. Grape Vinegar. Calif. Agr. Expt. Sta. Bul. 227 (1912), 26 pp.

PEACHES.

While the average sugar content of peaches is somewhat lower than that of apples, certain varieties contain enough sugar for vinegar making. Juicy varieties of the Carman type are best adapted for this purpose. The peaches should be tree-ripened if possible, for tree-ripened peaches apparently contain more sugar than those picked while green and allowed to ripen during shipment or storage.[4] Peach juice ferments readily and vinegar of good flavor can often be made from peaches which would otherwise be allowed to decay.

PERSIMMONS.

Persimmons, which grow in nearly all parts of the United States, but most abundantly in the Southern States, are exceedingly rich in sugar. Experiments conducted in the Bureau of Chemistry have shown that they may be utilized for making vinegar. In using fruits like persimmons and figs, which have a high sugar and low moisture content, water must be added in order to secure the proper concentration.

PEARS.

Grown in great abundance in many places, pears also may be utilized for making vinegar. Investigations in the Bureau of Chemistry have shown that even varieties like the Kieffer, which have a low sugar content, if well ripened may be made to produce a satisfactory vinegar.[5]

BERRIES.

Vinegar which can readily be made by household methods from raspberries, blueberries, and doubtless other berries may be very acceptable for certain purposes. Experiments in the Bureau of Chemistry have shown that vinegar made from red raspberries will retain indefinitely the odor and flavor of the fruit, which makes it desirable for flavoring food. Vinegar made from berries is dark, but it can easily be made clear or " bright " (p. 15).

HONEY.

Vinegar of excellent flavor can be made from unmarketable honey or honey washings. When honey is used for this purpose, it must, of course, be diluted by the addition of water until it contains about 15 per cent of sugar. As heat must be employed in the process of dilution, it will be necessary to use cultures of yeast and acetic bacteria (p. 12). The dilution of the honey also reduces the chemical elements which are necessary for the growth of the yeasts and bacteria. In order to supply the essential elements, especially nitrogen and phosphates, certain chemicals should be added. The following formula is suggested for a barrel of vinegar: Strained or extracted honey, 40 to 45 pounds; water, 30 gallons; ammonium phosphate, 2 ounces; potassium tartrate, 2 ounces.

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[4] W. D. Bigelow and H. C. Gore. Studies on Peaches. U. S. Dept. Agr., Chem. Bul. 97 (1905), 32 pp. Out of print, but may be consulted in libraries.

[5] H. C. Gore. The Preparation of Vinegar from Kieffer Pears. *In* J. Am. Chem. Soc. (1907), vol. 29, p. 759.

MAPLE PRODUCTS.

Maple-sirup skimmings or maple sirup which has been scorched may be used for making vinegar. Like honey, this must be diluted until it contains about 15 per cent of sugar, or until it weighs 9 pounds to the gallon. To each 30 gallons of the diluted sirup, 2 ounces each of ammonium sulphate and sodium phosphate are added. These chemicals, which are neither expensive nor injurious in the quantities called for, are not to be regarded as adulterants.[6]

WATERMELONS.

Watermelons have been used successfully for making vinegar, but the juice must be concentrated to about half its original volume to give the proper sugar content.

GRAINS.

Grains, chiefly corn, barley, rye, and oats, are largely utilized for the production of spirit and malt vinegar. The starch which they contain is first converted into sugar, usually by the action of malt (sprouted barley). Malt vinegar is made from the sugary solution or wort obtained by steeping crushed malt in warm water.

MOLASSES.

Molasses, either alone or in combination with grain extracts, is widely used as a basis for making spirit vinegar. Crude molasses, known as blackstrap, is first diluted with hot water and then subjected to alcoholic fermentation. The " low wines " which are obtained by distilling the fermented product are then run through generators and converted into spirit vinegar. Much of the spirit vinegar now used is made from alcohol obtained as a by-product from the manufacture of other products, notably compressed yeast.

Distilled or spirit vinegar which is made in this way is nearly colorless and lacks the aroma and flavor of fruit vinegars. For this reason it is not commonly preferred for table use, but is extensively used for pickling and preserving.

FERMENTATION.

The methods of making vinegar differ decidedly, depending upon whether it is made in small quantities as a household product, in larger quantities as a farm product, or in much larger quantities requiring the elaborate equipment of a commercial plant. The first two methods will be discussed in detail; the last method, which involves many technical details, can not be fully treated here.

HOUSEHOLD METHOD.

Fruit enough to make all the vinegar for a year's supply is wasted in many homes. Surplus or inferior grades of fruit not desired for immediate use or for canning may often be turned into a useful product at a merely nominal cost. Experiments in the Bureau of Chem-

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[6] Directions for Making a Good Flavored Cider Vinegar. Mich. Agr. Expt. Sta. Special Bul. 98 (1920), 24 pp.; A. E. Vinson. Honey Vinegar. *In* Ariz. Agr. Expt. Sta. Bul. 57 (1907), pp. 247–255.

istry have shown that vinegar of legal strength (4 per cent acetic acid) can be made from all of the fruits listed on page 2, although it may not be possible to use all varieties. In order to avoid disappointment, a test should be made to determine the sugar content of each lot of fruit before beginning the operation (p. 24). In making vinegar for home consumption and not for sale the need of a product of full legal strength is not imperative.

The best receptacles for making vinegar in the home are stone jars. These should always have straight sides and open tops and should be provided with covers. (Fig. 1.) Jars holding from 3 to 6 gallons are ordinarily used for this purpose.

With most of the fruits used it is impossible or inexpedient to separate the juice from the pulp before the alcoholic fermentation has taken place. The proper method, therefore, is to make a yeast inoculation into a mash of the fruit. With some fruits, like apples, oranges, or pineapples, from which the juice can be readily expressed, it may be better to use the juice only. Even with apples, however, it is probable that a more complete utilization of sugar would result if the alcoholic fermentation were carried out in the crushed fruit.

The following method which calls for peaches may be used, with a few minor variations, for making vinegar from other fruits.

PREPARATION OF MASH.

Ripe fruit should, of course, always be selected. Overripe fruit is not to be barred; in fact, in some instances it is preferable, so long as decayed portions, which would introduce objectionable flavors and organisms, are carefully removed. Juicy peaches are best, although almost any kind can be utilized.

Enough peaches (approximately 1 bushel) to fill a 4-gallon stone jar about two-thirds full when made into a mash are cut in two and crushed with a potato masher. The stones need not be removed.

ALCOHOLIC FERMENTATION.

A cake of compressed yeast which has been mixed in a small portion of the juice is added to the jar of peach mash. The jar is covered with a double layer of cheesecloth to prevent the entrance of insects and with a cover to exclude light. The mash is stirred daily to break up surface crusts, prevent the formation of molds, and insure a more complete fermentation. Stirring also prevents the action of acetic bacteria. As a rule from 4 to 6 days are necessary for this fermentation.

ACETIC FERMENTATION.

When the alcoholic fermentation is complete the juice is separated from the mash. Usually by this time separation has to a great extent been accomplished by the action of the yeast and straining through cheesecloth is all that is necessary. Complete separation may require the use of a hand press.

After the juice has been returned to the jar a starter (p. 13) in the form of vinegar is added in the proportion of 1 part to 4 parts of the juice and the jar is covered as before. Within a few days a thin coating or film will appear on the surface of the juice. This " mother

of vinegar," which is composed almost entirely of acetic bacteria, is essential for a successful fermentation. Great care, therefore, should be taken not to cause it to fall by stirring or agitation.

During the acetic fermentation frequent tests should be made to determine the increase in acidity (p. 25). As soon as this has reached its maximum, the vinegar is filtered (p. 15) and bottled (p. 19).

VARIATIONS.

This procedure may need to be varied in some respects for different fruits. For example, when fruits which have very high sugar contents, like persimmons, are used it is necessary to add water to the mash before inoculating with yeasts. An equal quantity by weight of water added to the persimmon mash will usually give the desired sugar content.

The plan outlined is believed to offer the best method of making vinegar in the household. It is the simplest and the least expensive and gives satisfactory results. Anyone who has a supply of surplus fruit, 2 or 3 large stone jars, a few cakes of compressed yeast, and 3 or 4 quarts of good vinegar to act as a starter can in this way make all the vinegar that is required by an ordinary family for a year. Vinegar with an acetic acid strength of 4.5 per cent has been made from peaches by this method in 13 days.

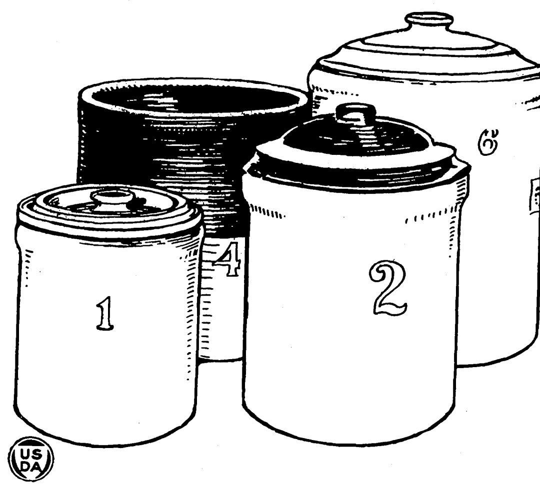

FIG. 1.—Suitable receptacles for making vinegar in the home.

FARM METHOD.

Vinegar as ordinarily produced on American farms is made from apple juice, although there is no good reason why grapes, peaches, or pears should not be used when their prices are not prohibitive.

PRESSING THE FRUIT.

Almost any apples may be used except those which are green or rotten. If partly rotten apples are used the rotten spots should be cut out and the apples washed. Dirty apples should be washed. Dirt, grass, or leaves should not be allowed to go into the press with the apples; they will injure the flavor of the vinegar and may retard the process.

The apples should not be ground too fine; they should be crushed rather than ground. Too fine grinding makes it difficult to press out the juice. Pressing must be done slowly and as much as possi-

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ble of the juice extracted. From 2 to 3 gallons of juice should be obtained from a bushel of apples. The "press cloth" type of press is the most efficient for this purpose. Full directions for pressing apples are given in Farmers' Bulletin 1264.

Second pressings from fresh pomace may be made when desired. If water is added to the pomace, however, the resulting juice will be low in sugar and other solids. The addition of such juice to the juice from first pressings may reduce the sugar content of the whole to a degree which would not permit the production of a satisfactory vinegar. If the vinegar is made for sale, Federal food regulations require that the addition of water in the process of manufacture must be plainly indicated on the label.

ALCOHOLIC FERMENTATION.

After being expressed, the juice should stand for a day or two in loosely covered barrels or other covered receptacles for sedimentation, after which it is carefully drawn off, preferably by the use of a siphon (p. 15), and transferred to other containers for alcoholic fermentation. These barrels should not be filled over three-fourths full.

Compressed yeast is added in the proportion of 1 small cake for each 5 gallons of juice. The yeast should first be thoroughly macerated in at least a quart of the juice and this should be well stirred into the whole. If a pure culture of a specially cultivated yeast is to be used, this should be prepared and added as directed on page 13.

ACETIC FERMENTATION.

The second or acetic fermentation may be done in any one of the three following ways. The selection of the process will, of course, depend upon individual conditions.

SLOW BARREL PROCESS.

After the alcoholic fermentation is complete, as shown by a test (p. 25), the juice should be carefully drawn off from the containers in which the alcoholic fermentation took place, without disturbing the settlings at the bottom, and passed into barrels for the final or acetic fermentation. The barrels should have been first thoroughly cleaned and soaked with strong vinegar and placed on their sides with the bungholes up. They are filled about two-thirds full, the aim being to expose as large a surface of juice as possible to the air. About 3 gallons of good vinegar is then added to each barrel to hasten the change to acetic acid. For this purpose a fresh unpasteurized vinegar is much to be preferred, but if it is not obtainable any good strong vinegar will do.

The alcohol of the yeast-fermented juice is now turned into acetic acid. In order that this change shall take place rapidly, the juice must be in contact with the air. For this reason the bungholes should be left open. Additional holes should be bored in the ends of the barrels to afford a free circulation of air. Pieces of cheesecloth or well-varnished fine wire screen should be tacked over all openings to keep out insects and dirt. The temperature should not be below 70°F., if practicable.

Acetification should be allowed to proceed until a strong vinegar is produced. Such a vinegar can be recognized by its taste, but it is much safer to determine the degree of acidity by tests as the acetification progresses (p. 25). If a good starter has been added and the juice is kept at the proper temperature, the time required to convert the alcohol in the juice into acetic acid should not be more than 3 to 6 months.

CONTINUOUS PROCESS.

The process of acetification may be made continuous by adopting the following plan,[7] which is essentially the Orleans method that has been used from time immemorial in the Orleans district of France:

A barrel holding about 50 gallons is made into a "converter" (fig. 2). In one end of the barrel, just above the center, a 2-inch hole (A) is bored and in the other end, about an inch below the stave containing the bunghole, another hole (B) of the same size. The holes are covered with mosquito bar or well-varnished fine wire screen to keep out the small vinegar or fruit flies. The spigot (C) is fitted in place. With the aid of a hot iron, a hole is bored through the cork used for closing the bung. In this hole is fitted the stem of a short glass or rubber funnel, running about half of the way through. A piece of bent glass tubing, about one-half inch in diameter and long enough to reach within 3 inches of the bottom of the barrel, is also fitted in the hole.

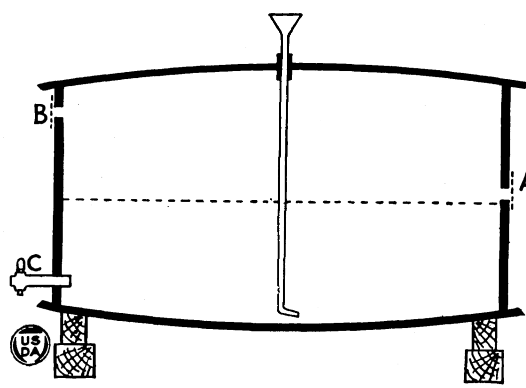

FIG. 2.—Converter for continuous process. *A* and *B*, 2-inch holes; *C*, spigot.

The finished converter is blocked firmly into place where there is a free circulation of air and about 3 gallons of fresh, unpasteurized vinegar is poured into it. The clear yeast-fermented juice is now run in until the surface of the liquid is nearly level with the air hole (A). Better results would probably be obtained by adding the juice in the fractional parts of one-fourth to one-third at intervals of a week. An additional advantage would be secured in all of these operations if the juice were heated to 85° or 90° F. before being poured into the converter.

The converter is allowed to stand without disturbing the film which forms on the surface until the acetification has gone far enough. When 4.5 to 5 per cent of acetic acid has been produced the vinegar is drawn off through the spigot, leaving about 3 gallons. The transfer of the vinegar should be made slowly so as not to break the film.

[7] Adapted from Farm-Made Cider Vinegar, Iowa State Dairy and Food Commission Bul. 12 (1915).

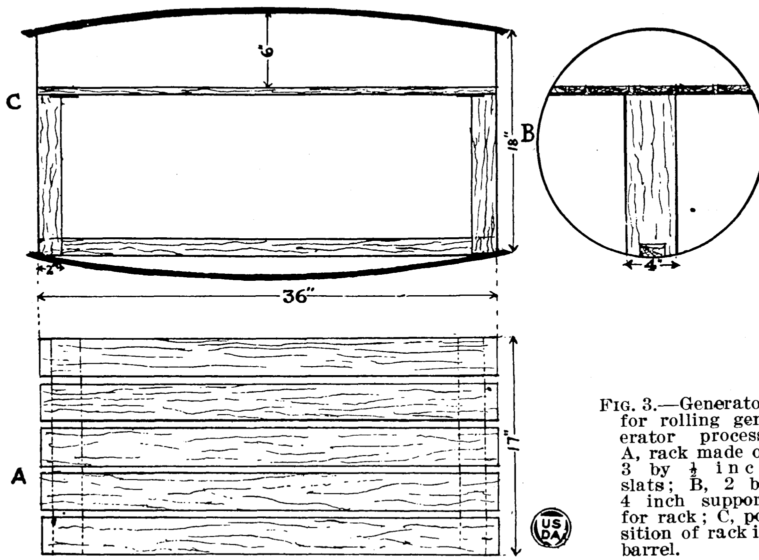

FIG. 3.—Generator for rolling generator process. A, rack made of 3 by ½ inch slats; B, 2 by 4 inch support for rack; C, position of rack in barrel.

A new supply of yeast-fermented juice is now slowly run in through the funnel which leads to the bottom of the converter. This should be done carefully so as not to disturb the surface film. The film will rise on the surface of the liquid and start fermentation promptly.

A converter made from a 50-gallon barrel should convert from 100 to 150 gallons of yeast-fermented juice into vinegar in a year.

ROLLING GENERATOR PROCESS.

The so-called rolling generator process, which greatly shortens the time required for acetification, approaches more nearly the commercial process of making vinegar in generators. This plan requires more work and attention than the slow barrel method, but by providing for a greater circulation of air it greatly hastens acetification.

An ordinary vinegar barrel is made into a generator [8] as follows (fig. 3): After one head of the barrel has been removed, a small rack is built into the barrel in such a way as to make throughout its length, about 6 inches below the bunghole, a compartment which is to be filled with beechwood shavings or corncobs (C). A quick way to do this is to make a rack of slats 3 inches wide by one-half inch thick, set into grooved end pieces, with about one-half inch of space between them (A). At each end this rack is supported by a 2 by 4 inch piece cut in such lengths that the rack will be at least 6 inches below the bung (B). The 2 by 4's are usually joined at the bottom by a crosspiece 1 by 2 inches. After this rack is set in place and the compartment is filled with cobs or shavings, the barrel is reheaded and three 1-inch holes are bored obliquely downward in each end, so that the openings come just beneath the bottom of the rack holding the shavings or corncobs. In constructing the rack and fastening it

[8] E. M. Chace. By-Products from Citrus Fruits. U. S. Dept. Agr. Cir. 232 (1922), pp. 4, 5. Out of print, but may be consulted in libraries.

to the 2 by 4's, grooves or dowels should be used, or, if more convenient, the rack may be held together by hardwood pegs. Iron or other metallic nails should not enter into the construction.

When used for the first time or after it has been standing idle for any length of time, the generator should be thoroughly scalded with hot water or steam. After the generator has been completely drained, about 1 gallon of fresh unpasteurized vinegar is poured into it. All the holes are tightly plugged, and the generator is turned to allow the vinegar to run over and saturate the shavings. The generator should then be filled about half full with yeast-fermented juice. Several times each day, if possible, but at least once a day, all the holes should be closed with wooden pegs and the generator rolled over, so that the bung is at the bottom, and shaken three or four times to bring the juice thoroughly in contact with the beechwood shavings or corncobs. The generator is then rolled back into its original position and the wooden pegs are replaced by cotton plugs. As there is a circulation of air from the end holes through the

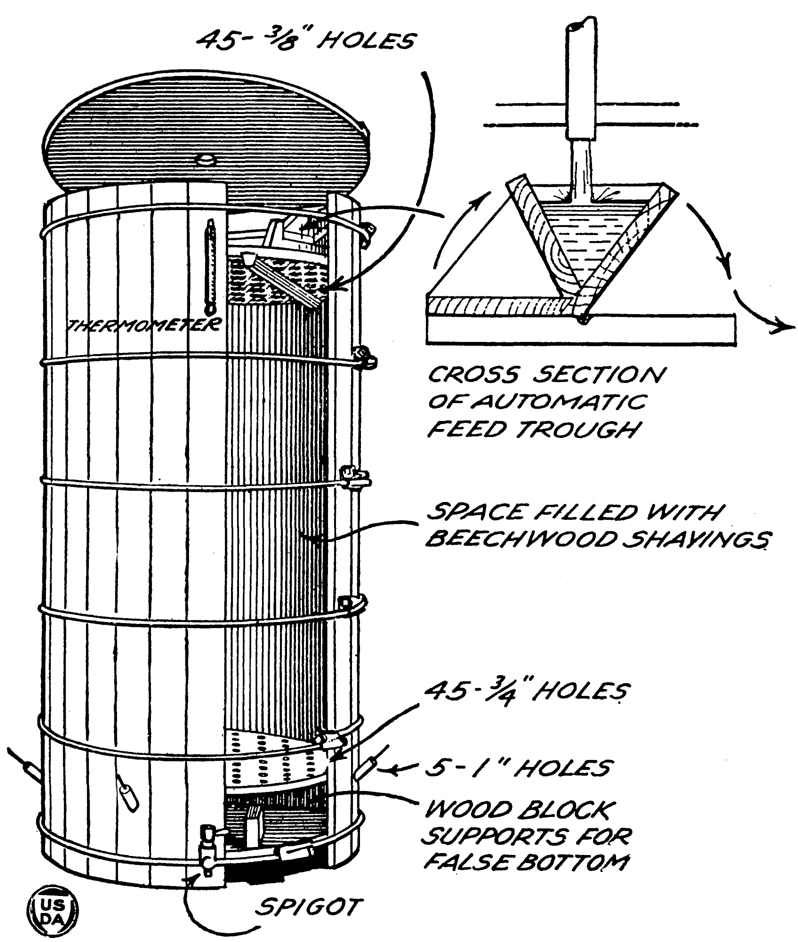

FIG. 4.—Generator for quick or generator process.

shavings out of the bunghole, the juice dripping from the shavings comes in contact with the air, as a result of which the process of acetification is greatly hastened.

As the fermentation progresses, a good deal of heat is developed. To obtain the best results the temperature of the upper portion of the generator should be kept at about 85° F. The temperature can be lowered by inserting some of the pegs to cut down the air current passing in at the holes. To raise the temperature the supply of air is increased by removing some of the pegs.

If the generator is rolled every day and the temperature is maintained at from 80° to 85° F., the juice may be converted into good vinegar by this method in from 60 to 90 days.

COMMERCIAL METHOD (QUICK VINEGAR PROCESS).

The farm method of making vinegar is necessarily slow, for the reason that only the surface of the alcoholic liquid is exposed to the air. It is possible to greatly hasten the production of acetic acid by allowing the alcoholic mixture to trickle slowly through a tall wooden vat containing material like wood shavings, coke, or corncobs which has been inoculated with acetic bacteria and through which a current of air is constantly rising. Such an apparatus is known as a generator (fig. 4) and this method is called the quick or generator process of making vinegar.

By using generators more vinegar can be made in a few days than could be made in as many months or even years by the ordinary farm procedure. For this reason generators are always used where vinegar is produced commercially in large quantities. As this method is a continuous process which calls for an extensive equipment and trained supervision, it is not practicable for farm use.

CLEANLINESS.

Cleanliness is essential in all methods. Anything that will produce malfermentation or off flavors should be avoided. To this end all utensils and receptacles must be kept clean. Not only must the barrels be clean but they must also be free from anything which will impart undesirable flavors or odors to the vinegar. Barrels which have been used for storing paints, oils, varnishes, or industrial alcohol should never be used for this purpose. Old vinegar and molasses barrels and new barrels should not be used until they have been well washed with boiling water or steam.

Barrels which have been used for grain alcohol, whisky, or brandy are well adapted for vinegar making. These liquors are antiseptic to most microbes, but in small quantities they are not antagonistic to the growth of yeasts or acetic bacteria and will not impart undesirable flavors or odors to vinegar.

USE OF STARTERS.

Experience has thoroughly demonstrated the value of the use of starters in making vinegar. Yeasts and acetic bacteria are practically always present in fruit juices, but they often occur only in limited numbers or more often are of undesirable or inactive types.

Better results are obtained by the addition of active strains. This is especially important in the alcoholic (yeast) fermentation where a prompt and rapid fermentation is desirable.

Ordinary compressed yeast, obtainable almost everywhere in this country, is a satisfactory starter for the alcoholic fermentation and should be used when it is impossible to obtain cultures which have been especially cultivated for vinegar production.

As a starter for the acetic fermentation, the best results are undoubtedly obtained by the addition of vinegar. If possible, unpasteurized vinegar should be used, for the reason that such vinegar usually insures the addition of the essential organism. Vinegar should be added as a starter in any event, however, whether or not it contains living bacteria, and even when a pure culture of acetic bacteria is used.

When pasteurized juices or sugar solutions, which do not contain the essential organisms, are used for making vinegar, the addition of active cultures is of course essential.

For those who desire to use pure cultures which have been cultivated especially for vinegar production these directions are given.[9]

The cultures should be obtained only from sources which insure their reliability. Such cultures are furnished by several of the State experiment stations and by some commercial laboratories. Yeast cultures should be obtained about a week before they are to be used. From these a starter in a 2-quart fruit jar is prepared for each barrel as follows:

STARTER FOR ALCOHOLIC FERMENTATION.

Wash the jar thoroughly and sterilize it in boiling water.

Immediately fill the jar half full with boiling apple juice. If no sweet juice is available, slice five or six ripe apples in 2 quarts of water and boil until the fruit is soft. Add 4 tablespoonfuls of molasses or 2 tablespoonfuls of sugar and strain about 1 quart of the boiling juice into the fruit jar.

Cover the jar immediately with a few folds of cloth, sterilized with boiling water, to keep out germs from the air.

When the liquid has cooled to 75° F., shake the bottle labeled "vinegar yeast" and empty the contents into the jar.

Keep the jar at a temperature of 70° to 80° F.

When foaming is very active, empty the contents of the jar into the barrel of sweet juice. Cover the bunghole with a thin cloth to keep out dust, without cutting off the air.

Immediately after the active foaming in the barrel ceases, send to the bacteriological laboratory for the acetic culture and prepare it as follows:

STARTER FOR ACETIC FERMENTATION.

Draw off a quart of the yeast-fermented juice into as many jars as there are barrels to be inoculated. Observe the foregoing precautions for keeping the jars clean and sterile.

Pasteurize the liquid in the jars by bringing it just to the boiling point in hot water; then allow it to cool to 75° F. Do not let it boil.

Add the culture labeled "vinegar bacteria" to the jar, cover as before, and keep it at a temperature of 80° F.

Do not disturb this jar. Mother of vinegar (*Bacterium aceti*) will appear on the surface of the liquid in a week or so as a smooth grayish-white glistening film. If molds develop do not use the starter but send to the bacteriological laboratory for another.

When this film is one-sixteenth to one-eighth inch thick, lift it out of the jar with a clean boiled splinter of wood, add the contents of the jar to the

[9] Adapted from directions given by the Washington State Agricultural Experiment Station for preparing pure cultures for vinegar making.

barrel, and float the film on the surface of the liquid, using the splinter as a raft. It is very important that this film be floated on the surface.

Do not disturb the barrel from now on except to remove small quantities from time to time to test the strength of the vinegar (page 25).

AFTER TREATMENT.

After vinegar has been properly fermented and has reached the desired degree of acidity, it is most important to see that it does not deteriorate in strength or quality. To this end, it must not be exposed to the air. The presence of air, which was so important during acetification, is now to the same degree undesirable. Free exposure to air would mean that the acetic and possibly other types of microorganisms would continue to act. As a result the acid would be attacked and sooner or later the vinegar would be reduced to a worthless condition. To prevent this, it is necessary only to keep the vinegar in completely filled containers, tightly sealed.

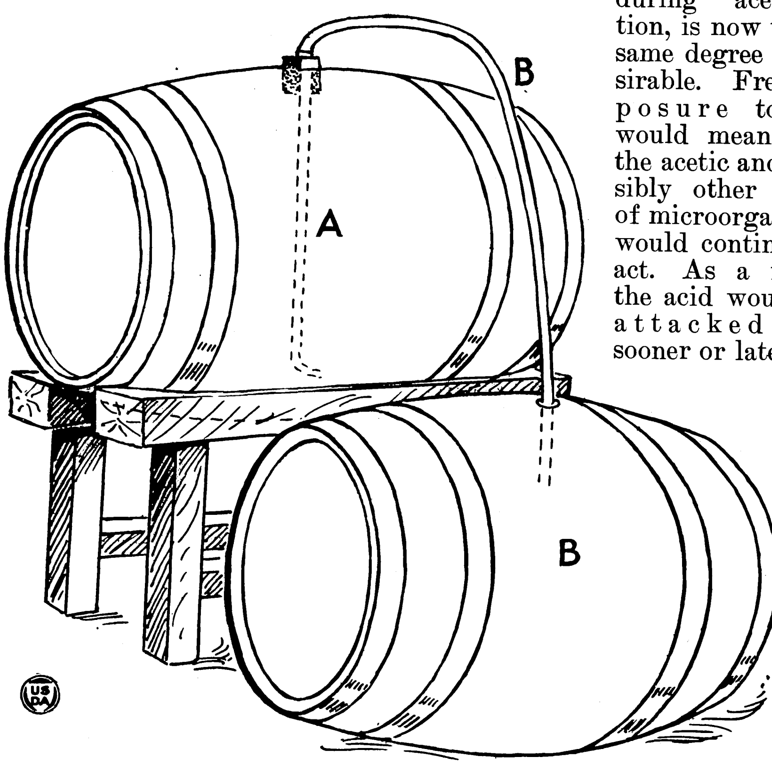

FIG. 5.—Siphoning off the vinegar. *A,* glass tube; *B,* rubber hose.

When vinegar is made under household conditions, as soon as it reaches the desired acidity it should be decanted off, filtered, and bottled. When made under farm conditions and stored in barrels or in kegs, the containers should be kept completely filled, tightly bunged, and stored, preferably in a cellar where a cool, even temperature prevails.

AGING.

Vinegar has a raw, biting taste when first made but it becomes more mellow during storage. The flavor and aroma characteristic of the best grades of vinegar made from apple and grape juice are due

to the esters which are formed during storage. Storage for from six months to a year is required for vinegar to attain its highest quality.

CLARIFICATION.

The aging of vinegar is valuable for the additional reason that it affords a chance for settling. In many cases vinegars which are not clear at the end of fermentation will become clear on standing.

After vinegar has been held in storage for several months it should be " racked off," that is, drawn off carefully, so as not to disturb the sediment, and with as little exposure to the air as possible. This is best done by the use of a siphon. (Fig. 5.) For this purpose the glass tube (A) described on page 9 may be utilized by simply attaching to the upper end a piece of rubber hose (B). This process should be repeated if the vinegar is to be held in storage very long. Usually this will yield a product which is fairly clear and for home use may be all that is desired. If intended for sale, however, good commercial practice demands that it be perfectly clear or bright.

Juices from certain fruits, notably that from most varieties of apples, show a marked tendency to clear during fermentation. Others, like that from peaches, do not, and often can be made perfectly clear only with great difficulty. Cloudiness in vinegar may be due to the presence of finely divided particles or colloidal substances held in suspension, or to the presence of bacteria or the products of bacterial activity. Certain strains of acetic bacteria show a marked tendency to produce cloudiness of the medium in which they grow. In order, therefore, that a vinegar may be perfectly clear and bright, it is usually necessary to resort to filtration or to the use of clarifying agents.

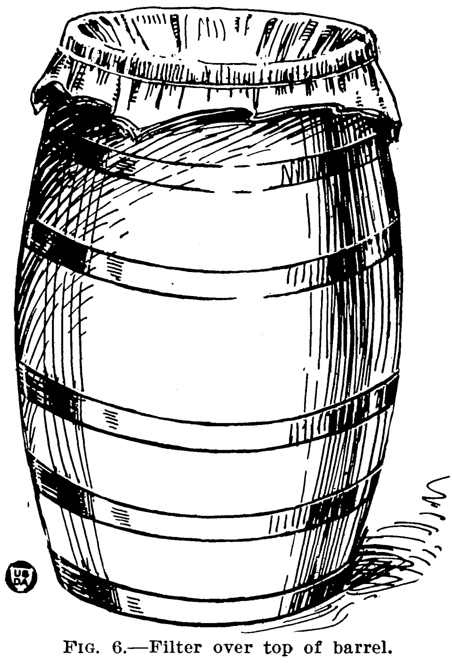

Fig. 6.—Filter over top of barrel.

FILTRATION.

The common method of securing a perfectly clear vinegar is by means of filtration, which usually is effectual if properly done.

When the quantity of vinegar to be filtered is not large, it may be passed through a filter made by folding a large piece of canton flannel so as to give two thicknesses or more. This may be simply placed over a convenient receptacle (fig. 6) or it may be made up in the form of a cone-shaped filter bag (fig. 7). It may be neces-

sary to pass the vinegar through a filter of this kind several times to make it clear or bright. The efficiency of a cloth filter, and in fact of practically all filters, depends upon the gradual filling up of the pores of the filtering medium by particles of the material passing through it. Hence perfect clarification is not often accomplished by one filtration, or at least the first portion to pass through is not clear and must be poured back for refiltration.

When larger quantities of vinegar are to be filtered, as in commercial production, filters of more or less elaborate construction are used. These usually operate by suction and filtration is made through various substances, such as cloth, paper or cotton pulp, or diatomaceous earth. Metals which are readily attacked by acetic acid must be avoided in the parts of the filter which come in contact with the vinegar.

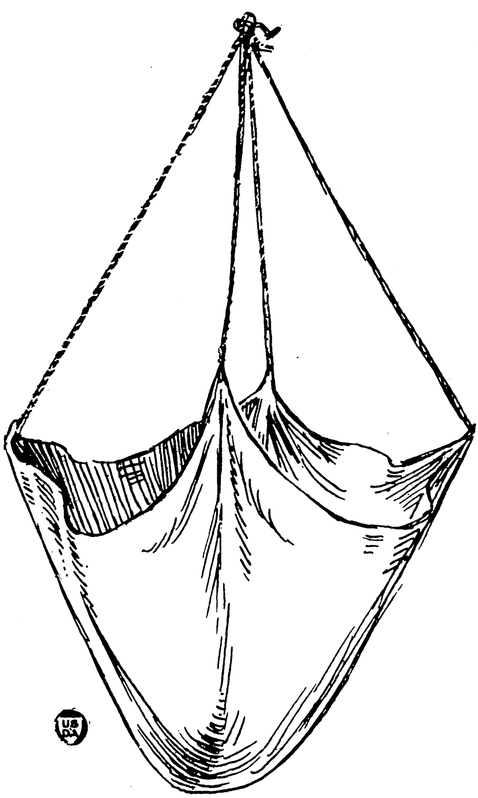

FIG. 7.—Filter bag.

CLARIFYING AGENTS.

In some vinegars which are persistently cloudy filtration alone may not be effectual for clarification. In such cases a clarifying agent, either alone or as an aid to filtration, must be used. An inert insoluble substance is preferred for this purpose.

Diatomaceous earth, commonly called kieselguhr, has a high adsorbing power and when properly selected and prepared has no undesirable effect on the product. If this earth contains calcium carbonate it should be rejected. The organic matter usually present to some extent can be removed by heating the earth to redness. It should be added to the vinegar in the proportion of one-half to 1 ounce to the gallon (4 to 6 pounds to 100 gallons), well stirred in order to form an intimate mixture with the vinegar, and at once filtered through a cloth containing a thin moist layer of the same earth.

Animal charcoal or some of the vegetable carbons are sometimes used for clarifying vinegar. These are open to certain objections, however. Animal charcoal, or bone char, usually contains alkaline salts, which, to some extent at least, would lower the acidity of the vinegar, and unfavorably affect its flavor. Another objection to the carbons, especially the vegetable carbons, is that the finer particles filter out with difficulty, so that, unless the filtering is very carefully done,

they may on standing form a deposit on the sides and bottoms of containers.

As the carbons are active decolorizing as well as clarifying agents, they are sometimes used for clarifying grape vinegars made from dark wines which might otherwise be unmarketable.[10] They must, however, be used with caution and only after a preliminary test to determine the quantity necessary in each case. They are to be thoroughly stirred into the vinegar just before filtration.

When vinegar is made in the home from fruits like prunes and various berries which give a dark-colored product, the color need not be removed. It is only necessary that the vinegar should be made clear or "bright."

Gelatinous or albuminous substances which produce a heavy precipitate when mixed with vinegar have long been used and are widely recommended as a means of clarification. When it is desired to clarify vinegar in this way one-half ounce of a good grade of edible gelatin to a barrel of vinegar should be used. The gelatin must first be covered with about a quart of water, allowed to stand for a few hours, and heated until completely dissolved. The solution is then added to the vinegar and mixed thoroughly by stirring. After standing for some time the gelatin settles, leaving a clear liquid. The clear liquid should be siphoned off (p. 15) and the sediment drained off and filtered. The success of this method of clarification depends upon the perfect precipitation of the gelatin which results from the presence of tannin. In many vinegars tannin is present in such small quantities that more tannin must be added if clarification is to be accomplished by the use of gelatin. The tannin (about one-fourth the quantity by weight of gelatin used) should be added several hours before the gelatin is added.

Ordinarily a clear vinegar may be obtained by the use of agents which act chemically and under certain conditions their use may be justifiable (p. 22). This method of clarification, however, is open to the following serious objections: (1) It means the addition of a foreign substance which goes into solution in the vinegar and may have an unfavorable influence on the flavor of the product; (2) these agents act slowly and their use involves loss of time and extra labor and expense; (3) the addition of some of these materials favors the growth of microorganisms and is therefore objectionable unless followed at once by pasteurization.

PASTEURIZATION.

Pasteurization is always to be considered as one of the measures for preserving vinegar and maintaining its strength. The deterioration of vinegar is usually the result of the continued activity of the acetic organisms. Even after filtration or clarification, vinegar contains bacteria which upon being exposed to the air grow and multiply, making the vinegar "mothery" and perhaps cloudy. This condition may be prevented by pasteurization, which is sometimes done as soon as acetification is completed. As the same end may be accomplished by storage in air-tight containers which are completely filled, however, pasteurization is usually deferred until the vinegar is transferred to its final containers.

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[10] F. T. Bioletti, loc. cit.

The proper temperatures for the pasteurization of vinegar range from 140° to 160° F. Experience has shown that if properly carried out a temperature of 140° F. is effectual for this purpose, but it is the minimum—no lower temperature can be depended upon to produce the desired result. On the other hand, a temperature of 160° F. should not be exceeded, for the reason that it is not required and may cause an unnecessary loss of acetic acid by evaporation.

Under household or farm conditions pasteurization may be accomplished by simply heating the vinegar to the required temperature in kettles or other large containers. Only the best unchipped enameled ware should be used. The entire volume of the vinegar must be brought to an even temperature. This can be done by stirring during the heating process and by using a reliable thermometer. After being cooled to about 70° F., the vinegar is at once transferred to the final containers, which should have been previously sterilized in hot water or steam. They should be filled full and immediately sealed with sterilized stoppers.

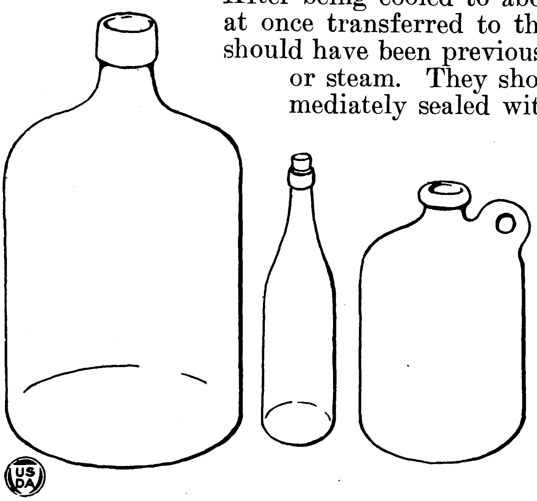

FIG. 8.—Glass containers for vinegar.

Vinegar may be readily pasteurized after it has been transferred to the final containers by submerging the tightly sealed containers in water and heating to the required temperature. For pasteurizing on a small scale, an ordinary tin wash boiler, with a wooden rack in the bottom to permit circulation of water and having a long-stemmed thermometer suspended through a hole in the cover, makes a very satisfactory outfit.[11] Jars or bottles should be placed in the boiler either on their sides or inverted in order to insure the destruction of any organism on the stoppers.

For pasteurizing vinegar on a larger scale or in large containers, a pasteurizing tank is necessary. Vinegar pasteurized in this way will not reach the desired temperature as soon as the surrounding water. This additional time, which is proportional to the size of the containers, varies from 5 minutes for a pint container to 25 minutes for one holding 2 gallons. Allowance must also be made for the expansion of liquids from heat. Containers, therefore, should not be filled entirely full. A rise in temperature from 60° to 140° F. would cause an expansion of about 2 per cent in volume.

Under commercial conditions vinegars are usually pasteurized by the continuous method. The vinegar is heated to the required temperature by being passed through coils of pipe surrounded by steam and then to other coils covered by cold water, which again cools it to

[11] J. S. Caldwell. Farm Manufacture of Unfermented Apple Juice. U. S. Dept. Agr. Farmers' Bul. 1264 (1922), pp. 33–34.

about 70° F. Under the usual factory procedure, vinegar that has been properly aged is first filtered, then pasteurized, and poured at once into the final containers.

Pasteurization also is believed to assist the maturing of vinegar, giving it a softer and more pleasing taste and aroma. This it probably does by hastening the combination of the residual alcohol in the vinegar with the acetic acid, thereby favoring the formation of esters.

PACKING.

After vinegar has been properly aged, filtered, and pasteurized, it should be finally packed in small containers. This is the best way to preserve it for home use and is the most acceptable form in which it can be offered for sale to the ordinary consumer. The common method of keeping vinegar in the barrels in which it was stored after acetification and drawing out from time to time the quantities needed for immediate use is not a good practice; it permits the entrance of air and interferes with the sedimentation of the vinegar.

For the final packing of vinegar, receptacles which are most suitable in form and size and which will not be attacked by the vinegar should be selected. Metal containers, of course, are not to be considered. The most suitable containers are glass bottles, jars, or jugs. (Fig. 8.) They should be filled full and tightly sealed.

Vinegar made in small quantities by household methods may be stored in bottles. These are also largely used under commercial conditions to supply customers who want to buy only in small quantities. Ordinary glass-top fruit jars can be utilized in the home. Perhaps the most desirable containers for both home and commercial use are glass jugs, which may be obtained in almost every size up to 2 gallons capacity, the 1-gallon jug being a favorite.

As stoppers for all these containers, except the fruit jars, ordinary wood corks may be used, but they should be of the best material and free from cracks. Corks are greatly improved by being soaked in hot paraffin. Paraffined corks should not be used to seal containers holding hot vinegar, however, for the reason that the paraffin would probably liquefy and soil the surface of the pack. When the vinegar is packed for sale, the corks should be well driven in and heated paraffin should be poured over the top. Glass-stoppered bottles are desirable for vinegar made in small quantities in the household, but they are often difficult to obtain and quite expensive. When fruit jars are used, only those which have glass covers should be selected. Metal covers should never be used for sealing vinegar. Even those which are cork-lined are undesirable.

After vinegar has been packed, the containers should be properly labeled. When it is made for sale, printed labels giving the following information are desirable: (1) Name and address of manufacturer; (2) kind and quantity of vinegar which the container holds; (3) strength, expressed as nearly as possible in grains (p. 27) or in percentage of acetic acid, or preferably in both.

CAUSES OF FAILURE.

The chief causes of failure in making vinegar are: (1) The use of material having too low a sugar content; (2) failure to recognize the fact that the making of vinegar involves two distinct fermentations

(alcoholic and acetic) and that the first must be completed before the second begins; and (3) failure to stop acetification at the proper time. All of these causes have been discussed elsewhere in this bulletin and the remedy indicated.

Various malfermentations due to the presence of undesirable or destructive microorganisms also cause failure. All material used for making vinegar is contaminated to some degree with undesirable organisms which may have a harmful effect on the fermenting juices and may even grow at the expense of the desirable organisms. The only sure means of preventing such a result is to sterilize the raw material and use pure cultures. This, however, is usually neither possible nor desirable.

Malfermentations may be caused by false yeasts, molds, or undesirable bacteria. The mycodermæ, yeastlike organisms which nearly always accompany fruits and fruit juices, often develop upon exposure to the air, forming a scum on the surface of the juice. These organisms, which are known as *Mycoderma vini*, often called wine flowers, like the true yeasts, multiply by budding, but, unlike the true yeasts, grow only in the presence of oxygen, for which reason they are called aerobic, and have no fermenting value. They live on the medium on which they grow, being destructive to both fixed acids and alcohol. The presence of mycodermæ is objectionable in all of the fermentation industries and the scum formed by them should be removed whenever possible. This scum, which at first is thin, whitish, and smooth, grows rapidly, soon becoming thick, rough, and heavily wrinkled. It should not be confused with the acetic film which at first usually occurs as greasy looking spots on the surface and gradually spreads, becoming a grayish veillike covering over the entire surface. As a rule the acetic film later becomes a smooth, leathery membrane, which eventually sinks by its own weight, only to be succeeded by another similar formation. This membrane is made up of acetic bacteria and a gelatinous material given off by them.

Mold spores are often present in fruit juices and under favorable conditions, either alone or in combination with false yeasts and aerobic bacteria, may grow on the surface of fermenting juices. As molds have an unfavorable action on the flavors of these juices, their growth should always be prevented if possible.

The bacteria which may complicate a fermentation are usually the kind that can grow in the absence of oxygen—the so-called anaerobic type. The lactic group, the one most commonly found, is nearly always present to some extent in fruit and vegetable juices. If these bacteria occurred in large numbers they would undoubtedly cause cloudiness, increased acidity, and undesirable changes and flavors. Other forms of bacteria, such as the butyric or even putrefactive types, may develop in juices, especially in those of low acidity. Unless speedily checked, these organisms may soon produce changes which make the juices worthless. The development of acetic bacteria before the acetification stage is, of course, very undesirable.

All these organisms usually appear before or during the alcoholic stage. As a rule they can be prevented by securing at the start an active alcoholic fermentation. This is accomplished by adding at once a culture of active yeasts and by subjecting the fermenting

juice to such favorable conditions as will render their growth rapid and certain. In this way they quickly gain precedence over all other organisms and the sugar in the juice is utilized before other organisms have an opportunity to attack it. The large quantity of carbon dioxide formed by an active yeast fermentation doubtless has a tendency to check the growth of all other organisms. Above all, it is important to secure complete utilization of the sugar before the acetic bacteria, which are always present to some extent, have an opportunity to form much acetic acid. The presence of even 0.5 per cent of acetic acid interferes seriously with the growth of yeasts and 1 per cent is almost prohibitive.

The failure of yeasts to grow in a juice which is ordinarily a favorable medium is probably due to a high acid content, or, in some instances, to the presence of an antiseptic agent added to prevent fermentation. It is useless to add more yeast to a juice of this kind. The only thing that can be done is to dilute it with fresh juice to a point where yeasts will grow and then add another culture.

Sometimes failure occurs during the acetic fermentation. Acetification may be slow in starting or may stop entirely, owing to the fact that the acetic bacteria are present only in small numbers or that those present are of a weak strain or of an objectionable type, like the *Bacterium xylinum.* In most cases failure is due to the fact that the medium is unfavorable to the growth of the acetic bacteria or that the temperature and air conditions are not favorable. As a rule acetic bacteria will grow in a medium which is only weakly acid or even slightly alkaline, but a more prompt and vigorous growth can usually be obtained in a decidedly acid medium. For this reason the addition of vinegar is always advisable, especially in the case of juices or solutions which are normally low in acid. The addition of vinegar also is a protection against the growth of undesirable organisms until enough acid is formed by oxidation of the alcohol present.

The solution to be fermented must contain the proper nourishment for both yeasts and acetic bacteria. The presence of sugar for the yeasts or of alcohol for the bacteria alone is not sufficient to insure their growth. Nitrogenous matter in some form must be present to make these organisms function properly. Fruit juices usually contain enough nourishment for the growth of yeasts and acetic bacteria, but not all the sugar solutions used for making vinegar do (pp. 4, 5).

Temperature is an important factor in making vinegar. If too high or too low this may be a cause of failure. Most yeasts do their work best at from 75° to 80° F., and most strains of acetic bacteria at from 80° to 86° F. As evaporation is likely to occur at these temperatures, somewhat lower ones are often preferred. If very much lower than those stated, the fermentations are certain to be slow. In general, it may be said that a very hot room or a very cold cellar is a poor place in which to make vinegar.

DARKENING OF VINEGAR.

Vinegar usually becomes darker with age. This slow darkening may be due to the presence of oxydase (an organic substance which promotes oxidation), just as fruits, vegetables, and fruit juices are

darkened when exposed to the air. Moderate darkening which comes on gradually in vinegar usually need cause no great concern.

In many cases darkening doubtless is due to the presence of small quantities of iron and tannin. The presence in large quantities of iron or tannin or both may cause the vinegar at once to become very dark and in extreme cases even densely black. Tannin, a normal constituent of nearly all fruit juices, is present, in small quantities at least, in vinegar made from these juices. Tannic substances may also be extracted from new barrels in which vinegar is stored, especially when they have not been properly cleaned. Iron salts are not a normal constituent of vinegar, but they may be present as a result of the action of acetic acid on iron during the process of manufacture. They may also gain entrance through soil which clings to the fruit from which the vinegar is made. In nearly every case excessive darkening of vinegar is the result of the presence of iron salts. The inky blackness commonly caused by the combination in solution of iron salts and tannin occurs when iron salts are present in a fruit vinegar. The degree of blackening depends entirely upon the quantity of iron salts present. It is important, therefore, to prevent the entrance of iron salts into vinegar in every way possible. Darkening from this cause can usually be removed by "fining" with gelatin (p. 17).

While animal charcoal and vegetable carbons are usually effective in removing color from solutions (p. 16), their use as decolorizing agents for vinegar is open to several serious objections.

Free exposure to air undoubtedly favors the darkening of vinegar, regardless of what special cause is operating to produce this result. This constitutes another reason for protecting vinegar from exposure to air as far as possible.

ANIMAL PARASITES.

VINEGAR EELS.

Vinegar may become infested with small worms (*Anguillula aceti* (Muel.) Muel.), commonly called vinegar eels. Although very small, they can be seen with the unaided eye by holding the vinegar in a small glass before a strong light. They are harmless when taken internally, but very objectionable from an æsthetic standpoint. As these eels are apparently found only in vinegar or in connection with fruits or other substances which are undergoing acetic fermentation, they undoubtedly spread from such sources. They usually occur around the edges of acetic liquids and in the surface of the film. When sufficiently numerous they may destroy the film, causing it to sink, thus interfering with acetification. When very numerous they may give rise to a putrid decomposition which makes the vinegar unfit for use.

Vinegar eels are readily killed by heat, a temperature of 130° F. being sufficient for their destruction. Heat, therefore, in some form is the best means of getting rid of them. They are easily removed from finished vinegar by filtration, followed by pasteurization. Barrels, tanks, and generators which contain them should be sterilized by steam.

VINEGAR MITES.

Unless great care and cleanliness are observed in connection with vinegar production, mites (*Tyroglyphus longior* L. and *Tyroglyphus siro* Gerv.) may appear in large numbers and prove very troublesome. They are undoubtedly identical with the mites often present in cheese and other food products.[12] Under favorable conditions of warmth and moisture, these mites breed with great rapidity, and unless proper precautions are taken they may enter vinegar casks and generators, spoiling the contents.

Mites are readily destroyed by the use of hot water or steam. If a room becomes badly infested, it should be cleaned, fumigated with sulphur, and thoroughly washed with kerosene emulsion. The entrance of mites into vinegar casks may be prevented by painting a ring of turpentine or kerosene oil around the openings.

VINEGAR FLIES.

Several species of light-brown flies (*Drosophila* spp.) breed in the juices of decaying fruits and also around the openings of vinegar containers or wherever they find vinegar exposed to the air. These are known as fruit or vinegar flies. If very numerous, the larvæ of these flies may get into the vinegar and cause its deterioration. They may also be responsible for the introduction of the *Bacterium xylinum*, an undesirable member of the acetic group.[13]

The presence of these flies may be prevented to a great extent by cleanliness and by avoiding the spilling of vinegar and the leakage from casks. The importance of keeping all openings in casks well screened has already been mentioned.

VINEGAR BEES.

Substances with such names as "vinegar bees" and "California bees" are sometimes advertised for use in making vinegar. As extravagant claims have been made for some of these preparations, a word of caution about them should be given. These so-called "vinegar bees" are not insects, as the name implies, but a combination of yeasts and bacteria in a suitable medium. As the "bees" are usually the result of chance inoculation, the yeasts present are not as a rule actively fermenting strains and the bacteria are ordinarily a mixed culture which may contain harmful as well as desirable types. Molds also are often present. Even if the "bees" should contain none but desirable microorganisms—that is, yeasts and acetic bacteria—their use would still be fundamentally wrong, for the reason that they would bring about the simultaneous action of alcoholic and acetic ferments which is to be avoided (p. 19).

TESTS.

In making vinegar certain tests are necessary for accurate results. Unfortunately there are no simple tests which are dependable. It is not safe to assume that the alcoholic fermentation is complete

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[12] L. O. Howard and C. L. Marlatt. The Principal Household Insects of the United States. U. S. Dept. Agr., Div. Ent. Bul. 4 (1896), pp. 100–111. Out of print.

[13] G. Bertrand. Préparation biochimique du sorbose. *In* Compt. rend. (1886), vol. 122. pp. 900–905.

when bubbling or frothing ceases; nor can tasting during the acetic fermentation be depended upon to show when the acetic fermentation has gone far enough. Reliable tests are needed to determine (1) the sugar content of the material from which the vinegar is to be made, (2) the quantity of alcohol formed during the first fermentation, and (3) the quantity of acetic acid formed during the second fermentation. They call for additional apparatus not ordinarily found in the home or on the farm.

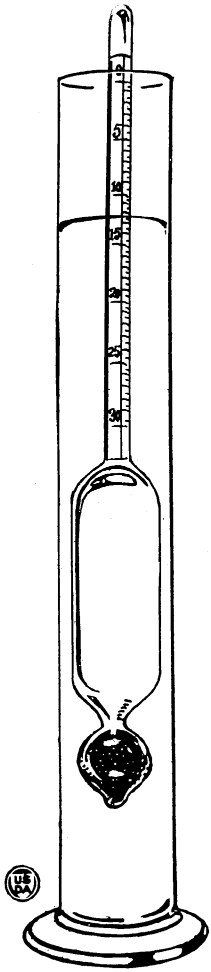

FIG. 9.—Sugar hydrometer.

SUGAR.

A quantitative chemical analysis is necessary to determine accurately the sugar content of the juice or solution used in making vinegar. Very few persons can make a test of this kind; moreover, great accuracy is not usually required. Ordinarily this information can be obtained with a sufficient degree of accuracy by the use of a sugar hydrometer[14] which shows the sugar content of any pure sugar solution. (Fig. 9.)

This test should, of course, be made before fermentation begins. The hydrometer should be cleaned thoroughly and dried each time before being used and it should be handled with clean, dry hands or with a clean cloth. The juice to be tested should be quite fluid—that is, it should not contain enough solid matter to make it thick or slimy; otherwise, the resting point of the hydrometer will be uncertain. A small quantity of the juice is poured into a glass cylinder, and the hydrometer is dropped in carefully. (Fig. 9.) The instrument must float freely and touch neither the bottom nor walls of the cylinder.

To determine the correct reading, put the eye on a level with the surface of the liquid and note where the true surface intersects the scale. The film of liquid which is drawn by capillarity up around the neck must be disregarded.

The specific gravity of juices varies with the temperature. Therefore the juice must be brought to the standard temperature for which the hydrometer is adjusted (usually 60° F.) or a temperature correction should be made. This correction is very nearly 0.1 per cent for every 3° F. above or below the standard. If the temperature is higher, this correction must be added; if it is lower, it must be subtracted.

The approximate percentage of sugar in fruit juices which corresponds to the hydrometer reading is shown in Table 1.

As fruit juices contain substances other than sugar which increase the reading, the true sugar content of these juices is always from 0.5 to 2.5 per cent less than that indicated by the hydrometer.

[14] Either a Brix or a Balling hydrometer may be used. A Brix hydrometer, graduated from 0 to 30, is well adapted to this purpose.

ALCOHOL.

As a result of the utilization of sugar during fermentation, the hydrometer reading gradually approaches the zero point. This instrument, therefore, may be used to determine the progress of a fermentation and its probable completion. When the quantity of material to be fermented is small enough to admit of its being weighed accurately, this information may also be obtained, with perhaps a greater degree of accuracy, by weighing the fermenting mass from day to day, thereby determining the loss of weight due to the escaping carbon dioxide. When loss of weight has practically ceased, the fermentation may be regarded as complete.

When the fermentation of a juice or sugar solution is complete it no longer contains sugar. This has been converted into alcohol and carbon dioxide gas, the alcohol remaining in the liquid and the gas passing into the atmosphere. The fermented juice should then contain a quantity of alcohol which approaches closely to that indicated by the original hydrometer reading. (Table 1.) The exact quantity of alcohol resulting from a fermentation can be determined only by distillation.[15]

ACETIC ACID.

The acid strength of a vinegar can be determined accurately only by titration against an alkaline solution of known strength. For this purpose normal sodium hydroxide is ordinarily used. The simplest way to do this is to measure carefully with a pipette 10 cubic centimeters of the vinegar to be tested into a porcelain evaporating dish, adding a few drops of a 0.5 per cent solution of phenolphthalein in 50 per cent alcohol as an indicator. The normal sodium hydroxide is then run in very slowly, preferably using a 50 cubic centimeter burette graduated in tenths of a cubic centimeter. As the sodium hydroxide is being added the juice should be stirred constantly. When the entire well-stirred mixture shows a permanent faint pink tint the neutral point has been reached.

The exact quantity of sodium hydroxide required to neutralize the mixture in the dish, multiplied by 0.6, gives the number of grams of acid per 100 cubic centimeters, calculated as acetic, present in the vinegar. For example, if the burette reading shows that 7.5 cubic centimeters of sodium hydroxide is required to neutralize the mixture, the grams of acetic acid in 100 cubic centimeters of the vinegar would be 4.5, which, for convenience, is usually stated as 4.5 per cent.

The apparatus and chemicals required for making these tests may usually be procured through local druggists, or they may be obtained from dealers in laboratory apparatus and supplies.

ACID STRENGTH OF VINEGAR.

Based on the molecular weight, every 100 parts of sugar should give about 51 parts of alcohol and 49 parts of carbon dioxide gas. As small quantities of sugar are consumed as food for the yeasts or

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[15] Alcohol determinations are not essential and are seldom made except in the commercial production of vinegar. Those who desire to make such a test should consult the methods of the Association of Official Agricultural Chemists or books relating to analytical chemistry.

may be lost in the production of other substances, however, no more than 45 to 47 parts of alcohol are obtained.

Theoretically, again, 100 parts of alcohol should yield about 130 parts of acetic acid. Because of evaporation and other causes, however, less than 120 parts are obtained. Hence, starting with 100 parts of sugar, it is possible, under very favorable conditions, to get from 50 to 55 parts of acetic acid. In order to insure a vinegar with 4.5 per cent of acetic acid, a juice which gives a hydrometer reading of about 12 should be used. (Table 1.)

TABLE 1.—*Hydrometer readings (Brix or Balling) of fruit juices, approximate percentages of sugar before fermentation, and percentages of alcohol that can be produced.*

Hydrometer reading (Brix or Balling).	Sugar.	Alcohol.	Hydrometer reading (Brix or Balling).	Sugar.	Alcohol.	Hydrometer reading (Brix or Balling).	Sugar.	Alcohol.
°	*Per cent.*	*Per cent.*	°	*Per cent.*	*Per cent.*	°	*Per cent.*	*Per cent.*
10.0	7.5	3.7	12.6	10.1	5.0	15.0	12.5	6.2
10.3	7.8	3.9	12.9	10.4	5.2	15.2	12.7	6.3
10.5	8.0	4.0	13.1	10.7	5.3	15.4	12.9	6.4
11.0	8.5	4.2	13.3	10.8	5.4	15.7	13.2	6.6
11.2	8.7	4.3	13.6	11.1	5.5	16.1	13.6	6.8
11.5	9.0	4.5	13.8	11.3	5.6	16.3	13.8	6.9
11.7	9.2	4.6	14.0	11.5	5.7	16.6	14.1	7.0
11.9	9.4	4.7	14.3	11.8	5.9	16.8	14.3	7.1
12.2	9.7	4.8	14.5	12.0	6.0	17.0	14.5	7.2
12.4	9.9	4.9	14.7	12.2	6.1			

The percentages of sugar given in Table 1 are 2.5 less than those indicated by the hydrometer readings. While this difference is not true of all fruit juices, it is true of many. Analyses of a large number of apple juices made by the Bureau of Chemistry have shown that the nonsugar solids usually constitute about 2.5 per cent of the juice. This difference affords a safe basis for the estimation of the probable results of a fermentation. The percentages of alcohol by weight given are half the sugar content. Common experience has shown that this is the usual result of a normal fermentation. As the percentage of acid formed by acetification as a rule exceeds by little, if any, the percentage of alcohol present, it is possible by a very simple calculation to estimate from the hydrometer reading of a fruit juice the strength of the vinegar it will produce. For example, if the hydrometer reading of a juice is 12.5, subtract 2.5 to get the percentage of sugar. This result, divided by 2, gives 5 as the probable percentage of acetic acid which should be obtained in the finished vinegar. Owing to various causes which have been explained in this bulletin, such a result is by no means always obtained. The only method for determining the actual strength of the vinegar obtained is the use of a test for acidity.

The acid strength of vinegar is determined by finding the acidity of the vinegar in terms of grams of acetic acid per 100 cubic centimeters. Since the specific gravity of vinegar is but slightly greater than that of water, 100 cubic centimeters of vinegar weigh little more than 100 grams. Grams per 100 cubic centimeters is therefore nearly but not quite the same thing as percentage by weight. The difference is so slight that it is usually disregarded by manufacturers

and dealers and the strength of the vinegar is stated as 4, 5, or 6 per cent, etc.

The grain system of expressing the strength of a vinegar is also often used. As now used in this country, the grain, which is the unit of this system, is equivalent to 0.1 gram of acid per 100 cubic centimeters of vinegar. A 4 per cent vinegar therefore is a 40-grain vinegar; a 6 per cent vinegar is a 60-grain vinegar; etc.

FEDERAL REGULATIONS GOVERNING THE MANUFACTURE AND SALE OF VINEGAR.

Vinegar may be made in the home and on the farm without a permit if it is to be consumed only in the home or on the farm where it is made. If it is to be offered for sale the maker must obtain a permit from the collector of internal revenue of his district. As the regulations governing the making of vinegar for sale are subject to change, anyone planning to make vinegar on a commercial scale should first obtain the most recent information about the laws from the district supervisor, Alcohol Tax Unit, Bureau of Internal Revenue, in the district in which the plant is to be located.

All vinegar which is shipped from one State to another or is offered for sale in any possession or Territory of the United States or the District of Columbia should meet the requirements of the Federal Food, Drug, and Cosmetics Act. This information may be obtained from the Food and Drug Administration, Federal Security Agency, Washington, D. C.

As practically all States have laws governing the sale of vinegar, anyone interested in its commercial production should obtain the regulations from the State food commissioner.

In general, it may be said that the law requires that vinegar offered for sale in the United States should contain at least 4 per cent of acetic acid.

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U. S. GOVERNMENT PRINTING OFFICE: 1941

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